



Information and Communication Technologies

EPIWORK

Developing the Framework for an Epidemic Forecast Infrastructure

<http://www.epiwork.eu>

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FFCUL Progress Report on WP3

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Work package participants

The following partners have taken active part in the work leading to the elaboration of this document, even if they might not have directly contributed writing parts of this document:

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Change log

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Executive Summary

The report includes a summary of the work carried out by FFCUL in the first year of the project.



FFCUL Progress Report 2009.02.01 to 2010.01.31

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10th of February 2010

Abstract

The report includes a summary of the work carried out by the LASIGE group of FFCUL in the reporting period, the first year of the project life. The work by the CMAF group of FFCUL in WP1 is reported in a separate document.

Keyword List: progress-report, first-year

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1 Overview

The Epiwork project started in February 2009 and will run for 48 months. This report summarises the progress in the first two semesters of the project activity by the LASIGE group of FFCUL.

According to the work plan FFCUL is involved in the following work packages:

WP 1	Population Models and Contact Networks
WP 3	Information platform
WP 4	Epidemic Modelling Platform
WP 7	Management

The FFCUL participation in Epiwork involves two groups:

- CMAF Group
- LASIGE Group

The LASIGE team working on WP3 and W4 in this period includes:

- Mário J. Silva (FCUL Faculty, worked in the reporting period in WP3, WP4 and WP7)
- Fabrício Silva (FCUL Faculty, worked in the reporting period in WP3 and WP4)
- Francisco Couto (FCUL Faculty, worked in the reporting period in WP3)
- Luís Lopes (Post-doc researcher, worked during the reporting period part-time - 50% - while completing coursework on the Masters in Biomedical Informatics at FCUL on various tasks in WP3). Started working full-time in since the 1st of July, 2009.
- Hugo Ferreira (Graduate student, hired in April for 3 months with a part-time scholarship, to help in setting up the hardware infrastructure that will support

the information platform of WP3). Hogo was re-hired full-time after the Summer, being 100% dedicated to the project since September 1st, 2009.

- Carla Patrícia Sousa (Undergraduate student, hired in April with a scholarship, to help in setting up the hardware infrastructure that will support the information platform and give technical support to the deployed information platform of WP3). She was initially hired with a 50% dedication, which became 60% after the 1st of July.
- Graduate student João Zamite worked informally (effort not accounted) with our group in the development of prototypes for epidemic data collection from internet data sources (WP3) until the end of July 2009. He was later hired to work full-time in Epiwork under a scholarship that started on September 1st 2009.

There is a discrepancy between the profiles of the people hired to work on Epiwork at LASIGE and the planned, the reason being that we were unable to fill the software engineer and a post-doc positions as planned, with previous directly related experience and salaries matching our budget. As a result, we have been using Informatics Engineering and Biomedical Informatics students on the infrastructure setup assisted by FCUL faculty and senior technical staff.

LASIGE has hired more people at a reduced cost, which was the contingency measure found to manage the situation. We expect that in the next future they will graduate, acquire the required skills while working in the project and eventually match the envisioned profiles.

2 Work in WP1 — Population Models and Contact Networks

The CMAF group of FFCUL is participating in this task and sending a separate progress report.

3 Work in WP3 — Information platform

This task is lead by FFCUL, with a total contribution of 82 persons.month (60 hired technicians + 22 academics).

3.1 Background Information on WP3

Work package number	3		Start date or starting event:			Month 1		
Work package title	Information platform							
Activity type	RTD							
Participant number	12	1	2	3	4	5	9	10
Participant short name	FFCUL	ISI	FGC-IGC	TAU	MPI-DS	AIBV	BIU	FBK-IRST
Person-months per participant	82	60	4	8	42	2	11	6

The whole WP3 activity is structured into four tasks:

Task 3.1 – Data Collection.

Participants: FFCUL, ISI, FBK-IRST, BIU, MPI-DS, FGC-IGC, AIBV.

Description: Realistic simulations of epidemic processes crucially depend on the availability of datasets describing human behaviour and pathogen-host interactions. Datasets include population movement data, social and behavioural data, health related data, geographic data, detailed geo-temporal epidemic incidence and immunization data, pathogen evolution and multi-strains circulation data. Data can come from a variety of different sources, including hospital records, country statistics, Web content, and others. It can range from a global scale, such as the worldwide air transportation infrastructure, down to the

detailed description of individual activities at a minute-by-minute scale. This task will create a catalogue of databases of epidemiological data across Europe, with extensive meta-data describing the main characteristics of the available information sources. This catalogue will be integrated with a collaborative platform that will be setup for online discussion and exchange of meta-data among the participants.

Task 3.2 – Meta-Model Design.

Participants: FFCUL, IGC, ISI.

Description: While some of the previously mentioned datasets are freely available on the Web (e.g. WHO Global Health Atlas, Eurostat), they are often scattered in different repositories, cover partial regions of the world and come in different formats, according to different standards and classifications. The project envisions a unified and integrated approach for the management of these resources, with the design and implementation of an Epidemic Marketplace Platform, publicly available on the web. The platform supports the sharing and management of epidemic datasets and resources as well as their rating, annotation, and selection. It is an on-line social networking site that will serve researchers, practitioners, and educators all over the world to foster a virtual community for epidemic research. It will support the exchange of resources as well as user interactions. Based on a Web2.0 approach, users will become active participants, sharing information and data, and collaborating online, rather than being satisfied with a passive information consumer/viewer role. We envision proposing a simple reference format, which will facilitate the navigation and use of the datasets. Each dataset will come with a metadata file, signalling the date of submission, the last update, the source of the dataset, a basic profile (e.g., transportation network – Origin-Destination matrix), and a more thorough description of the dataset and the classification used. The Marketplace will support flexible and intuitive tools for navigation and selection of resources. Standard classifications as well as tagging systems proposed by users will be supported.

Task 3.3 – Epidemic Marketplace Platform.

Participants: FFCUL, ISI.

Description: This task will implement a platform based on the integration of grid technology and publicly available services and software on the web to support the sharing and management of epidemic datasets and resources as well as their rating, annotation, and selection. The Epidemic Marketplace Platform will be an on-line social networking site that will serve researchers, practitioners, and educators all over the world to foster a virtual community for epidemic research. It will support the exchange of resources as well as user interactions. Based on some of the Web2.0 characteristics, users will become active participants, generating information and providing data for sharing, and collaborating online, rather than being satisfied with a passive information consumer/viewer role. More specifically, researchers can use and contribute to the Marketplace in several different ways. They can: (1) use it as a catalogue of data sources containing the metadata describing existing databases; (2) view, download, tag, and comment on the available resources; (3) provide compliant datasets and relevant information; (4) use it as a forum where to publish information about their own data, seek modellers to collaborate with, share and distribute their new findings.

Task 3.4 – Evaluation and monitoring of the use of the catalogue and collaboration services.

Participant: FFCUL.

Description: This task involves the monitoring of epidemiological data exchanges performed through the mediating services platform. The evaluation will assess not only the coverage of the catalogued resources, but the users' satisfaction with the user interface and integrated collaborative tools made available through the epidemiological marketplace platform. More importantly, the analysis of the collected datasets and their annotations and usage will provide a rich environment for deriving an epidemiology ontology, which will

help further on the integration and communication among the community of epidemiologists.

3.2 Progress in the Reporting Period

In the first year, the work done by the LASIGE Team was related to Task 3.1 Task 3.2 and Task 3.3. Evaluation work in Task 3.4 will start once the information platform is deployed.

Activities at FFCUL in the first year of the project in this work package:

1. Mário Silva, and Fabrício Silva attended Epiwork Kick-off Meeting in Torino in February – presentation by Fabricio Silva; discussion with ISI on the joint work on WP3/WP4.
2. FFCUL and ISI had a videoconference on integration WP3/WP4.
3. Luis Lopes and Fabrício Silva attended WP5 Meeting in Amsterdam in May; presentation by Fabricio Silva and discussions on the Integration of WP3/WP4/WP5.
4. Deliverable 3.1, *Meta-model Initial Specification, Catalogue of relevant Data, Platform Requirments*, was distributed on schedule to consortium members on September, 30th.
5. Mário Silva, Fabrício Silva and Patrícia Sousa attended the 1st Epiwork Meeting in Torino in November. Mário Silva presented the overall progress of WP3 and the plans for developments ahead, Patrícia Silva gave a tour of the Epidemic Marketplace prototype and assisted Epiwork members in registering as users at the event.
6. FFCUL and ISI co-organized joint WP3/WP4 meeting in Torino on November, 18th, just after the 1st Epiwork meeting. Fabricio Silva presented the technical details of the Epidemic Marketplace Architecture.
7. The setup at FCUL of the hardware and base Software infrastructure to support the data and computational platforms of Epiwork was concluded by

October 2009. We now have two Dell Servers and two Iomega storage units operational as the backbone of the Lisbon Epiwork platform for WP3/WP4. .

8. Initial design of the software architecture of the Epidemic Marketplace was completed.
9. FFCUL Initiated in September 2009 the development of a second prototype of a data collector
10. Initiated in September 2009 the development of an initial prototype of the Epidemic Marketplace services.
11. Initiated in October 2009 the development of an Epiwork meta-data editor for epidemic datasets, following the policies outlined in deliverable D3.1.
12. The first operational prototype of of the Epidemic Marketplace was presented in the November 2009 meeting in Torino, and made available to Consortium members since then. The URL of the Epidemic Marketplace protoype is <http://epiwork.di.fc.ul.pt>.
13. Initiated in January 2010 the deployment of a new version of the EM base software, to be based in Fedora Commons version 3.0 and the Drupal Content Management System. This new version will substitute the current, based on Fedora Commons 2.2.2 and Muradora 1.3.3.

Publications and Presentations:

1. Presented paper to Inforum 2009 (<http://inforum.org.pt/INForum2009>), which was accepted for presentation in September at the conference: *Automated Social Network Epidemic Data Collector*. Luis F. Lopes, João M. Zamite, Bruno C. Tavares, Francisco M. Couto, Fabrício Silva and Mário J. Silva.
2. Wrote Invited Paper for ICDL 2010 (<http://www.teriin.org/events/icdl/>): *Building a Digital Library for Epidemic Modelling*. Mário J. Silva, Fabrício A. B. da Silva, Luís Filipe Lopes, Francisco M. Couto. (http://xldb.fc.ul.pt/xldb/publications/Silva.etal:BuildingADigital:2010_document.pdf)

3. Presentation in Torino, kickoff meeting of the Epiwork project, February 2nd and 3rd, 2009. (<http://www.epiwork.eu/2009/02/03/kickoff-meeting-of-the-epiwork-project/>)
4. Presentation in Amsterdam, WP5 first meeting, 25-26th of May, 2009. (<http://www.epiwork.eu/2009/06/05/first-epiwork-wp5-meeting-in-amsterdam-25-26th-of-may-2009/>).
5. Presentations in Torino, 1st Epiwork Meeting, 16-18th November 2009.
 - a. WP3 Progress presentation + WP3 outcast presentation (talks by Mário J. Silva)
 - b. EM Architecture presentation (talk by Fabrício Silva)
 - c. Epidemic Marketplace tour (talk by Patrícia Sousa)

Activities at FFCUL in the first year of the project in Task 3.1:

The data collection activity by the consortium will start once the first functional prototype is deployed and released to the consortium (at the end of the first year). In the first semester, we started with some initial experiments, involving:

- Initial catalogue design. This involved designing the conceptual model for managing large datasets that is now under development.
- Design and implementation of a data collection prototype based on the twitter API and development platform (flu-related tweets)
- Initiated in September 2009 the development of a second prototype of a data collector
- Initiated in September 2009 the development of an initial prototype of the Epidemic Marketplace services

Activities at FFCUL in the first year of the project in Task 3.2:

Work in this task included:

- A review of meta-modelling techniques and existing standards.

- Characterisation of the data sources most commonly used in epidemiological studies.
- Initial design of the epidemic meta-data catalogue.
- Initiated in October 2009 the development of an Epiwork meta-data editor for epidemic datasets, following the policies outlined in deliverable D3.1.

Activities at FFCUL in the first year of the project in Task 3.3:

- Definition of the general architecture of the Epidemic Marketplace. This has involved joint discussions with WP5 on how data collected data by IMS in different countries is aggregated in datasets and uploaded to the Epidemic Marketplace. Privacy and anonymization issues have emerged. It is possible to perform these data processing operations at various stages in the information processing pipeline. The interlinking of the IMS data with other
- Infrastructure design and identification of equipment to be acquired for Epiwork.
- Installation of the hardware and base software (OS)
- Configuration and implementation of fault tolerance support for the epidemic marketplace: backup and data replication policies
- EM services installation, including Epidemic Marketplace's Repository main components: Fedora Commons (www.fedora-commons.org) and Muradora (<http://www.muradora.org/muradora>). The Repository is now accessible to authenticated users from <http://epiwork.di.fc.ul.pt/muradora/>.
- Deployment of a first prototype version of the Epidemic Marketplace Forum, based on phpBB, <http://www.phpbb.com/>.
- The first operational prototype of the Epidemic Marketplace was presented in the November 2009 meeting in Torino, and made available to Consortium members since then from <http://epiwork.di.fc.ul.pt>.
- Initiated in January 2010 the deployment of a new version of the EM base software, to be based in Fedora Commons version 3.0 and the Drupal Content

Management System. This new version will substitute the current, based of Fedorca Commons v2.0 and Muradora.

- Discussions with partners involved in WP3 on how to identify relevant datasets to the catalogue and strategies and incentives for populating the Epidemic Marketplace.

Activities at FFCUL in the first year of the project in Task 3.4:

- Planning of the monitoring tasks. Actual collection of usage data will start once the initial system is fully deployed.

3.3 Effort Allocation

The effort allocated to WP3 in the reporting period is as follows:

WP3 FFCUL Reporting Period	Effort (p.m)
Semester 1: M1-M6: February 1, 2009 to August 31, 2009	4.13 (2.18)
Semester 2: M7-12: September 1, 2009 to January 31, 2010:	15.25 (2.35)
Year 1: February 1, 2009 to January 31, 2010	19.38 (4.53) Total: 23.91

The commitment to the project in the period was 23.91 persons.month, 19.28 pm from technicians, and 4.53 p.m from permanent staff.

This is now well above planned (assuming a 10.25 p.m constant effort/semester), and reflects the decision of hiring more (and less skilled) staff for the FFCUL/LASIGE team of Epiwork in Semester 2.

3.4 Outcast for WP3

The outcast for WP3 is outlined in the SWOT analysis chart that we prepared for the last internal Epiwork project meeting, shown below:

WP3 SWOT Analysis

Strengths <ul style="list-style-type: none">• Epiwork-driven EM• Standards-based• Open Source modules• Supported (until 2013)	Weaknesses <ul style="list-style-type: none">• Unpopulated EM• What are the incentives?• Interfaces to WP4 and WP5?• Compelling scenario?
Opportunities <ul style="list-style-type: none">• Epiwork testbed• Creation of a baseline for epidemic modelling• Showcase for partners' outputs	Threats <ul style="list-style-type: none">• Consortium enters "everyone for himself" mode.• "Somebody will take care of that" attitude• Someone turning EM into a very expensive complex and useless cache (not likely)

Some of the activities that we plan to undertake until deliverable D3.2 is released in September 2010 are:

- Populate the Repository with information that will make it an useful tool to the epidemic modelers community.
- Publish the EM Middleware APIs
- Release the EM data Collector
- Replace Muradora and the phpBB forum, by a the Drupal Content Management System.

Later on, the envisaged activities will mainly involve:

- Continuing work on populating and documenting the EM Repository.

- Addressing Ethics, Privacy and Anonymization issues that must be tackled by the Epidemic Marketplace before it is publicly announced.
- Incorporating in the systems of project partners a Distributed Authentication and Access control mechanism.
- Providing tools for selecting datasets or parts of the information thereof from the EM collection for retrieval access by epidemic modelling tools.
- Replicating the Lisbon EM node at another partner.

4 Work in WP4 — Epidemic Modelling Platform

This task is lead by ISI, with a total contribution of 19 persons.month (12 hired + (7) academics).

Activities at FFCUL in the first year of the project in this work package:

- Meeting in Torino, February 2009
- Videoconference in May with ISI, discussions of service-oriented architecture to be deployed and how the two computational platforms will work together and provide services to the consortium and the community.
- Joint WP3/WP4 meeting in Torino, in November 2009. Discussions on how the Epiwork Marketplace could become the data exchange for the simulation and visualization tools under development in WP4.

4.1 Effort Allocation

The effort allocated to WP4 in the reporting period is as follows:

WP3 FFCUL Reporting Period	Effort (p.m)
Semester 1: M1-M6: February 1, 2009 to August 31, 2009	2.97 (0.30)
Semester 2: M7-12: September 1, 2009 to January 31, 2010:	2.75 (0.20)

WP3 FFCUL Reporting Period	Effort (p.m)
Year 1: February 1, 2009 to January 31, 2010	5.72 (0.50) Total: 6.22

The commitment to the project in the period was 6.22 persons.month, 5.72 pm from technicians, and 0.50 p.m from permanent staff.

This is as planned, reflecting the fact that this task is led by ISI and our contribution will intensify later, as we settle on a common software architecture, including interfaces, for orchestrating and running services on both platforms. The reported effort by technicians reflects the splitting of the effort dedicated to setting-up the hardware and base software of the epiwork infrastrucure in Lisbon between WP3 and WP4.

5 Work in WP7 — Management

This task is lead by ISI.

FFCUL Effort in this task: 4 persons.month.

Activities at FFCUL in the first semester of the project in this work package:

1. Mário Silva attended the Epiwork quick-off meeting in Torino, February 2009.
2. Mário Silva attended the Epiwork 1st project meeting in Torino, November 2009.
3. Data collection activities for preparation of the 1st semester report and this annual report.

5.1 Effort Allocation

The effort allocated to WP7 in the reporting period is as follows:

WP3 FFCUL Reporting Period	Effort (p.m)
Semester 1: M1-M6: February 1, 2009 to August 31, 2009	0.0 (0.55)
Semester 2: M7-12: September 1, 2009 to January 31, 2010:	0.0 (0.55)
Year 1: February 1, 2009 to January 31, 2010	(1.10) Total: 1.10

The effort dedicated to the project in the period was 100% contributed by permanent staff, as planned.

EPIWORK, Report February 2009:

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February 13, 2010

1. Scientific background and activities: Main tasks in Workpackage 1 are modelling and parameter estimation in influenza, seasonal and pandemic, and investigation of network models for the spread of transmittable diseases like influenza and others, especially in the context of spatially restricted networks. Modelling and data analysis of vector borne diseases and the interplay between vector and pathogen ecology are further topics.

Predictability of outbreaks is in this context of major importance, as it can be quantified by system theories like deterministic chaos and criticality, i.e. prediction horizons given by Lyapunov exponents (especially in simple epidemic already showing large parameter regions of deterministic chaos) and large scale fluctuations of system size as observed near critical thresholds (as they become more and more relevant in evolutionary biological pathogen systems).

These basic notions are vital for the data gathering and analysis in the other work packages of the EPIWORK project, as well as the feedback from the more applied work packages are vital for the modelling and parameter estimation part in workpackage 1.

In accordance with these premisses we from the CMAF bio-mathematics team performed during the first year of EPIWORK the following activities:

We organized two conference special session at the international conferences, at CMMSE in Gijon Spain in July 2009, and ICNAAM 2009, held in September 2009 in Rethymno, Greece, focussing in our presentations and those of other invited participants on influenza modelling and parameter estimation, spatially restricted networks with superdiffusion and predictability in basic epidemiological multi-strain models, as typical for among others influenza and dengue, at ICNAAM e.g. with 14 talks. Further we organized a CIM/SPM jornada (Centro internacional de Matematica, Sociedade Portuguesa de Matematica) in November 2009 with 12 talks in a joint effort with a Darwin legacy conference at CMAF, Universidade de Lisboa.

As a summarizing event for 2009 and initiating our activities for 2010, from our bio-mathematics group we organized 1. to 3. of February 2010 an international workshop “Dynamical Systems Applied to Biology and Natural Sciences (DSABN 2010)” at CMAF with more than 50 participants from Italy, France, Netherlands, UK, India, Brazil, USA, Check Republic and Portugal with strong

participation from EPIWORK members (all CMAF members: Frank Hilker, Philip Gerrish, Sebastien Ballesteros, Nico Stollenwerk, all presenting talks and posters, further EPIwork members presenting talks were Gabriela Gomes, who gave the word to Sander van Noort, and Flavio Coelho). Topics from these and further speakers were among others epidemic modelling and data analysis of influenza and vector borne diseases, pathogen evolution, and mathematical techniques applicable to epidemiological and ecological modelling. (see <http://ptmat.fc.ul.pt/~dsabn2010/>)

Other activities performed during the first year of the project EPIWORK are:

Sebastien Ballesteros has successfully defended his PhD thesis working at CNRS in Paris in december 2009 on influenza modelling and data analysis, and is since 1. January 2010 employed on the EPIWORK project to work in the CMAF group. Over the last year Sebastien has already participated in CMAF-group and EPIWORK activities, like giving talks in CMAF and special conference session organized by CMAF and joining the EPIWORK meeting at ISI in November 2009, including presentation there.

Informal talks have been held with Forschungszentrum Juelich, Germany, and CNRS in Paris, France, each on institute's leaders level, on how to obtain good influenza data, how to build up internet surveillance systems in the respective countries in central Europe, and on scientific and computational aspects involved in WP 1 and EPIWORK as a whole. This has been done in close contact with initiators of Influenza net in the Netherlands. These contacts have been intensified over the summer.

Networks with spatial restrictions have been intensively investigated by several members of CMAF, inside and outside the Mathematical Biology group, visible through the seminar series at CMAF over the last half year. Ecological aspects of vector borne diseases and evolutionary aspects of influenza like illnesses have been investigated by Frank Hilker and Philip Gerrish, and presented internationally. Predictability in multi-strain epidemiological models and under seasonality is currently investigated by Nico Stollenwerk in collaboration with Maira Aguiar, both CMAF, and Bob Kooi, University of Amsterdam. Progress has been made especially on fast calculations on prediction horizons, results presented in CMAF, at CMMSE in Gijon, Spain, in Belo Horizonte, Brasil. Basic reinfection models necessary to understand spreading of influenza like illnesses have been investigated, publications in international journals are just accepted, further under submission. A book on evolutionary aspects of multi-strain epidemiology has been completed and is currently in production. It will lead to intensified research activities on evolution of influenza viruses and its implications to modelling and data analysis among the students in CMAF and collaborators outside, especially the ones from work package 1 in EPIWORK. The workshop DSABN 2010 at CMAF has among other results brought together experts on mosquito ecology like Eduardo Massad, Claudio Struchiner and Yves Dumont, necessary to interact with Frank Hilker and Gabriela Gomes on vector borne disease modelling in Workpackage 1.

A PhD-course proposal on bio-mathematics has been accepted in January 2010 by the science faculty of Lisbon University, which will bring students to research level, this with strong thematic influence of ongoing research activities in the

modelling part of the EPIWORK project. The courses will be coordinated by Nico Stollenwerk and Joao Boto, who is also involved in the superdiffusive epidemic network project, and will be given in part also by other EPIWORK members, Philip Gerrish and Sebastien Ballesteros.

We are in the process of negotiations with the president of the European Society of Mathematical and Theoretical Biology (ESMTB), Carlos Braumann, on a thematic year 2011 on bio-mathematics, including a summer school and second edition of DSABN. In case of successful negotiations the epidemiological modeling as performed in EPIWORK will be of mayor importance in this effort, as well as these will be outreach activities of EPIWORK on European wide level.

2. Scientific dissemination and management:

2.1. Talks given to international audience (conferences):

- 30.6.-3.7.2009 Talk by Nico Stollenwerk "Analytic likelihood function for data analysis in the starting phase of an influenza outbreak"
at the 'International Conference on Computational and Mathematical Methods in Science and Engineering, CMMSE 2009' in Gijon, Spain.
- 30.6.-3.7.2009 Talk by Nico Stollenwerk "Fractional calculus and Levy flights: modelling spatial epidemic spreading"
at the 'International Conference on Computational and Mathematical Methods in Science and Engineering, CMMSE 2009' in Gijon, Spain.
- 30.6.-3.7.2009 Talk by Sebastien Ballesteros (successfully hired on EPIWORK position)
"Introducing gradual antigenic drift in co-circulating cross reactive antigenic cluster models"
at the 'International Conference on Computational and Mathematical Methods in Science and Engineering, CMMSE 2009' in Gijon, Spain.
- 30.6.-3.7.2009 Talk by Maira Aguiar (co-authors N. Stollenwerk, B. Kooi) "Computational aspects in the investigation of multi-strain dengue models"
at the 'International Conference on Computational and Mathematical Methods in Science and Engineering, CMMSE 2009' in Gijon, Spain.
- 18.-22.9.2009 Talks at the '7th International Conference of Numerical Analysis and Applied Mathematics, ICNAAM 2009'
in Rethymno, Greece, by Phillip Gerrish, Nico Stollenwerk and Maira Aguiar.
further talks later in the year, Torino, Nov. etc.

2.2. Invited talks given to national and international audience (institutes):

- 3.-4.2.2009 Talk by Nico Stollenwerk on "Mathematical modeling and data analysis in epidemiology and population biology"
at the kick-off meeting for the EU project EPIWORK
at ISI, Torino, Italy.
- 10.2.2009 Talk by Nico Stollenwerk "From simple spatially extended epidemic models towards realistic spreading of diseases"
at CMAF, Universidade de Lisboa, Portugal.
- 28.4.2009 Talk by Sebastien Ballesteros "Disentangling non-linear dynamics and punctuated immune escape in complex recurrent pattern of human influenza A"
at CMAF, Universidade de Lisboa, Portugal.
- 19.5.2009 Talk by Nico Stollenwerk "Epidemiology of Dengue Fever: A Model with Temporary Cross-Immunity and Possible Secondary Infection Shows Bifurcations and Chaotic Behaviour in Wide Parameter Regions"
at Universidade Federal de Minas Gerais, Belo Horizonte, Brasil.
- Feb./March 2008 visits to FZJ Jülich, Germany, and CNRS Paris, France,
for the EU project EPIWORK.

2.3 Poster presentations at international conferences:

- 18.-22.9.2009 Poster "New chaotic attractor in dengue:
Positive Lyapunov exponent in multi-strain model with
temporary cross-immunity" during
the '7th International Conference of Numerical
Analysis and Applied Mathematics, ICNAAM 2009'
at Rethymno, Crete, Greece.
- 1.-3.2.2010 Poster presentations at "Dynamical systems in Biology
and Natural Sciences", Lisbon, Portugal (see list below)

References

Publications in refereed international journals:

- [1] Martins, J., Pinto, A., & Stollenwerk, N. (2009) A scaling analysis in the SIRS epidemiological model, *Journal of Biological Dynamics* **3**, 479–496.
- [2] Aguiar, M., Stollenwerk, N., & Kooi, B. (2009) Torus bifurcations, isolas and chaotic attractors in a simple dengue fever model with ADE and temporary cross immunity, *Intern. Journal of Computer Mathematics* **86**, 1867–77.
- [3] Martins, J., Aguiar, M., Pinto, A., & Stollenwerk, N. (2009) On the series expansion of the spatial SIS evolution operator, *accepted for publication in Journal of Difference Equations and Applications*.

Books:

- [4] Stollenwerk, N. & Jansen, V.A.A. (2010) **Population Biology and Criticality**, *From critical birth-death processes to self-organized criticality in mutation pathogen systems: The mathematics of critical phenomena in application to medicine and biology*, (book in production by Imperial College Press, London).

Refereed conference contributions in scientific books:

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